

Effect of Dolomite as Expansive Agent and Shrinkage Reducing Admixture in Self-Compacting Shrinkage – Compensating Concrete

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Abstract

The principle of using expansive agents has been recommended to manufacture shrinkage compensating concrete provided that an adequate wet curing is carried out. On the other hand, shrinkage-reducing admixture (SRA) in the concrete mixes, has been more recently suggested to reduce the risk of cracking in concrete structures caused by drying shrinkage.

This paper is devoted to the study of the influence of complex modifier in the form of superplasticizer, shrinkage reducing admixture and expansive agent CaO- MgO-based on the fresh properties, hardening process and restrained shrinkage of Self-Compacting-Shrinkage-Compensating Concretes. The combined addition of shrinkage-reducing admixture with expansive agent has been found to be successful in producing shrinkage-compensating concrete. It should be noted also that the shrinkage reducing admixture slightly improve the workability of the fresh concrete mixtures but, it slightly reduces the early compressive strength of concrete.

Key words: Self-Compacting-Shrinkage-Compensating Concrete, Drying shrinkage, Superplasticizer, Shrinkage reducing admixture, Restrained shrinkage, Expansive agent.

الخلاصة

مبدأ استخدام العامل التمددي يوصى به في الكثير من الابحاث والدراسات لإنتاج خرسانة تعويض الانكماش بشرط وجود معالجة رطبة كافية. من ناحية أخرى، في الآونة الأخيرة اقترح استخدام مضافات مقللة للانكماش في الخلطات الخرسانية للحد من خطر التشققات في المنشآت الخرسانية والناجمة عن انكماش الجفاف.

تضمن هذا البحث دراسة تأثير إضافات معدلة متعددة الوظائف (الملدن الفائق، مضافات مقللة للانكماش، ومعامل التمدد) على الخواص الطرية وعملية التصليب والانكماش المقيد للخرسانة ذاتية الرص-تعويض الانكماش. وجد ان استخدام العامل التمددي والمضافات المقللة للانكماش بشكل مشترك تكون ناجحة في انتاج تمديد مقيد في الخرسانة يعوض عن الانكماش الذي يحدث فيها نتيجة جفاف الخرسانة. وتجدر الإشارة أيضا ان المضافات المقللة للانكماش تحسن قليلا من قابلية التشغيل للخلطات الخرسانية الطرية ولكنها تقلل وبشكل طفيف من مقاومة انضغاط الخرسانة في الاعمار المبكرة.

الكلمات المفتاحية :- التعويض الذاتي للانكماش، انكماش، الجفاف، الملدن الفائق، المضافات المقللة للانكماش، مقيدات الانكماش، مضافات التمدد .

1. Introduction

Self-compacting concrete (SCC) is an innovative type of concrete developed in Japan. SCC does not require manual compaction and has enough mobility without aggregate segregation if dropped from a specified height. It has the filling capacity and the necessary fluidity required to flow through congested reinforcement detailing

without sedimentation (Domone, 2007). Owing to the fact that it does not require vibration to compact, it is very helpful in reducing the concrete placing costs, enhancement of working conditions and prevention of health hazards resulting from vibrations (Lino *et.al.*, 2012).

Drying shrinkage is a volume contraction which occurs in the concrete during hardening, caused by moisture loss. If drying shrinkage could take place freely, without any restraint, it wouldn't represent any problem for most structural and non-structural concrete elements. Unfortunately, because of the presence of internal and external restraints (steel reinforcement, linkage with other portions of the structure, subgrade friction in slab on grade, etc.) drying contraction is partially, or totally, hindered and transformed in tensile stresses. While concrete is a brittle material, drying shrinkage stresses are often large enough to exceed the tensile strength of the concrete, resulting in cracks formation. Drying shrinkage cracks represent one of the main problems affecting reinforced concrete structures and elements since they are often cause of early deterioration, loss of serviceability or, simply, aesthetic defects formation (Neville *et.al.*, 2010).

One of the ways to reduce the shrinkage and cracking from shrinkage is to use chemical admixtures such as shrinkage – reducing admixtures (SRA). The effectiveness of SRA must be ascribed to the decrease in the surface tension of water. This reduces the capillary tension caused by the formation of water menisci developed in capillary pores and responsible for the shrinkage of the cement paste (Gettu *et.al.*, 2002; Mora-Ruacho *et.al.*, 2009; Saliba *et.al.*, 2001). On the other hand, due to the dosage of SRA (about 4 kg/m³) and its price (about 4-5€ in Europe) the extra – cost of 1 m³ for the SRA addition is relatively expensive (about 12-20 €/m³), because the restrained shrinkage can be mitigated about not completely eliminated Collepardi *et.al.*, 2005).

The technology of shrinkage-compensating concrete is based on the use of special products, such as calcium sulpho-aluminates or calcium oxide, which react with water and produce a restrained expansion in reinforced concrete structures. This technology has been invented many years ago (Neville, 1995), but its use has been very limited in practice due to the difficulty in adopting a continuous water curing absolutely needed in the early ages after setting. The expansion based on CaO and MgO have been studied (Chatterji, 1995; Nagataki, 1998; Lawrence, 1995; Mullick, 1998).

Of these, the authors are interested in MgO-based expansive agents, especially in those burned at lower temperature than that of ordinary Portland cement. MgO reacts with water to form Mg(OH)₂ that causes volume expansion about 118%. The dead burned MgO reacts with water very slowly; that causes the expansion to take place after the solidification of cement. Thus, the content of MgO in ordinary cement is restricted to less than 5%, and can be 6% if cement is sound examined by autoclaving testing in cement standards in many countries. Mehta and Pritz (Mehta *et.al.*, 1990).

proposed that high-MgO cement can be used to compensate shrinkage. The combined use of SRA and a CaO-based expansive agent has been studied (Collepardi, 2005) in order to check the potential success in producing shrinkage-compensating

concrete even in the absence of any type of curing. It was found out that CaO based expansive agent along with the combination of SRA produced a synergetic effect.

2. Experimental Program

2.1. Raw Materials

Ordinary Portland cement (OPC) which conforms to Iraqi Specification No. 5/1984 and class F fly ash (FA) as cementitious materials as well as two types of chemical admixture: superplasticizers on the basis of modified acrylic polymer Dynamon SR - 3 (Mapei, Italy) with specific gravity 1.07 and shrinkage-reducing admixture, on the basis of polypropylene glycol polymer Mapecure SRA 25 (Mapei, Italy) with specific gravity 0.85 have been used.

Dolomite ($\text{CaMg}(\text{CO}_3)_2$) is a kind of primary sediment mineral and has a widespread geologic distribution. It is used to obtain the expansive agent based on calcium and magnesium oxides by burning it at 1200 for one hour and then it was ground to powder with particle size 50-200 μm .

Crushed gravel in the saturated surface dry condition with a maximum diameter size of 10mm and a corresponding specific gravity 2.66 has been used as a natural aggregate. The grading of coarse aggregate and fine aggregate are shown in Table (1).

Table (1): Grading of Fine and Coarse Aggregate

Sieve size (mm)		Accumulated percentage passing (%)		Limit of Iraqi specification No. 45/1984	
Fine Aggregate	Coarse Aggregate	Fine Aggregate	Coarse Aggregate	Fine Aggregate, Zone (2)	Coarse Aggregate (10 mm)
4.75	37.5	94.2	100	90-100	----
2.36	20	86.6	100	75-100	----
1.18	14	70.7	100	55-90	100
0.60	10	40.1	90.8	35-59	85-100
0.30	5	8	17.5	8-30	0-25
0.015	2.36	2.6	2.3	0-10	0-5

2.2. Experimental Process

To determine the effect of SRA on the properties of self-compacting concrete the formulations (A-0; A-1; A-2; A-3) with the different content of admixture were prepared. The proportions of the concrete mixtures are listed in table 2.

Table 2: Composition of the concrete mixtures

Concrete mixture	A-0	A-1	A-2	A-3	B-0
OPC (kg/m^3)	455	455	455	455	455
Normal weight aggregate (kg/m^3)	1660	1660	1660	1660	1630
Fly ash (kg/m^3)	90	90	90	90	90
CaO-MgO expansive agent (kg/m^3)	0	0	0	0	36
Dry superplasticizer (kg/m^3)	4.0	4.0	4.0	4.0	4.0
SRA (l/m^3)	5.0	5.5	6.0	6.5	5.0
Water (l/m^3)	169.4	168.9	168.4	167.9	169.4
w/cm (effective)	0.32	0.32	0.32	0.32	0.32

The technological properties of SCC were determined in accordance with the BS EN 12350: Part 8: slump-flow, Part 10: L-box test. (100mm) concrete cubes were prepared to evaluate the compressive strength of concrete. The average strength of three specimen was obtained for each testing age: 7-28-56-90 days. All specimens remained in water storage tank until the time of testing.

Restrained expansion and restrained shrinkage of self – compacting shrinkage – compensating concrete were measured in accordance with ASTM C878/C 878M-0.9. Molds for casting test specimens when used in conjunction with the restraining cage provide for forming prisms 50mm square with a gage of 250mm. Restraining cage, consisting of a threaded low –carbon steel rod (Zinc –Coated) with steel end plates held in place by hex nuts.

Concrete mixture was placed in the mold in two approximately equal layers (the first layer just covered the threaded restraining rod), each layer was consolidated by ridding. After consolidation was completed the specimens were covered with a polyethylene sheet to prevent loss of moisture at the surface of the specimens. The specimens were removed from the molds at the age of 10 h. After the initial comparator reading, the specimens were cured in time –saturated water at $20 \pm 2^\circ\text{C}$ until they had reached on age of 7 days. Every day and at the end of the curing period another comparator readings were taken. Further, samples were removed from water, put on substrates for subsequent exposure to 28 days in air at a relative humidity 45-55% under ambient temperature $+25 \dots +32^\circ\text{C}$ (dry conditions).

Restrained expansion and restrained shrinkage measurements are carried out according to the ASTM test method C878/C 878M-0.9. Figure 1 indicates the metallic formwork where fresh concrete is placed by embedding a steel bar reinforcement (6 mm in diameter, 280 mm in length). At about 10 hours when the reinforced concrete specimen, with two metallic plates (50*50 mm) at the ends, is demoulded (Figure 1). the initial length of the steel bar is measured and then the reinforced specimen is immersed under water at $20 \pm 2^\circ\text{C}$ until they had reached on age of 7 days. The length-change of the steel bar is then recorded as a function of the curing time. Further, samples were removed from water and then exposed to 28 days in air with R. H. of 45-55% under ambient temperature $+25 \dots +32^\circ\text{C}$.



Fig. 1. Mold with restraining cage

3. Results and discussion

3.1. The influence of SRA on the technological properties of SCC concrete mixtures and compressive strength.

After preparing the allmixes, the workability of SCC can be characterized by the following properties: filling ability, passing ability, segregation resistance, flowing ability, by using slump flow, T50 cm, and L – box tests. Table (3) shows the slump flow (final diameter D) values and T500 for SCC mixes. Mix containing the higher dosage of shrinkage reducing admixture gave higher slump flow diameter and the lower is the viscosity from other mixes.

Table 3: fresh and hardened properties of SCC concrete

№	Flow ability SF, mm	Viscosity T ₅₀₀ , S	L-box H ₂ /H ₁	Compressive strength,			
				R ₇	R ₂₈	R ₅₆	R ₉₀
A-0	577	3.7	0.81	36.4	45.8	49.9	55.6
A-1	599	3.2	0.84	33.6	44.3	49.5	55.1
A-2	635	2.2	0.85	31.3	39.4	48.3	54.2
A-3	666	2.0	0.87	29.5	38.8	47.6	52.3
B-0	569	3.9	0.79	27.3	36.8	40.1	47.3

The development of compressive strength is given in table 2. For all concrete mixtures, we observed a reduction in strength for specimens with the higher dosage SRA. This diminution could be due to the fact that the SRA leads to an increase of average pore diameter, and consequently to a decrease of the mechanical strength observed.

3.2. The influence of complex modifier (expansive admixture and SRA) on the restrained expansion and restrained shrinkage of SCC concrete.

According to the results of the research of the expansion of concrete in restrained conditions, it was found out that the concrete, which contains the complex of modifiers "SRA + expanding components", during the whole period in water of research (up to 7 days), shows the higher remaining expansion from other mixes $\varepsilon = 331 \mu\text{m/m}$ (fig. 2). And when samples placed in hot, dry condition up to 28 days the expansion of concrete decreased and the lower restrained shrinkage characterized for mixes containing the complex of modifiers "SRA + expanding components" $\varepsilon = -100 \mu\text{m/m}$.

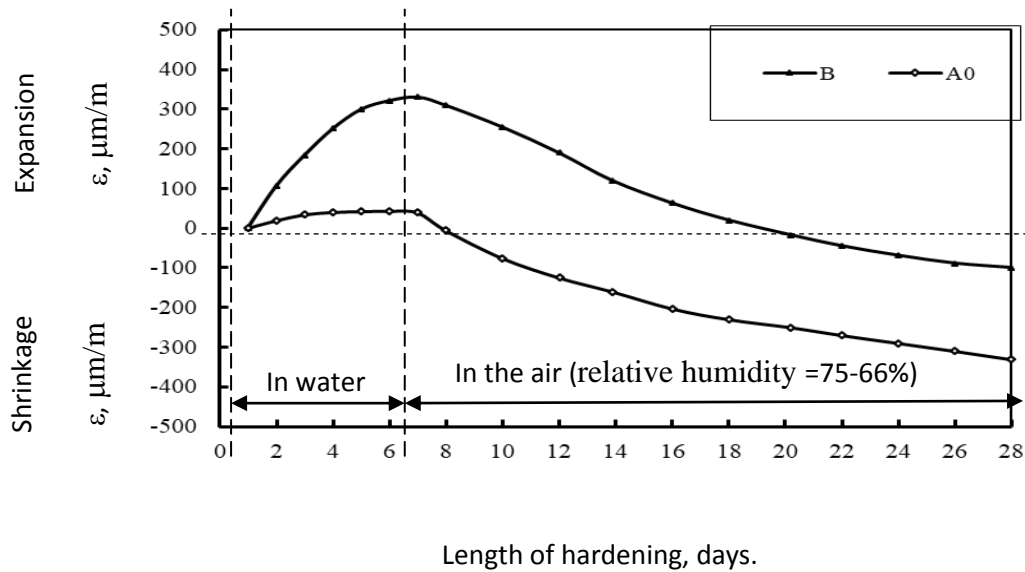


Fig. 2.The influence of the composition of modifiers on restrained expansion and restrained shrinkage SCC

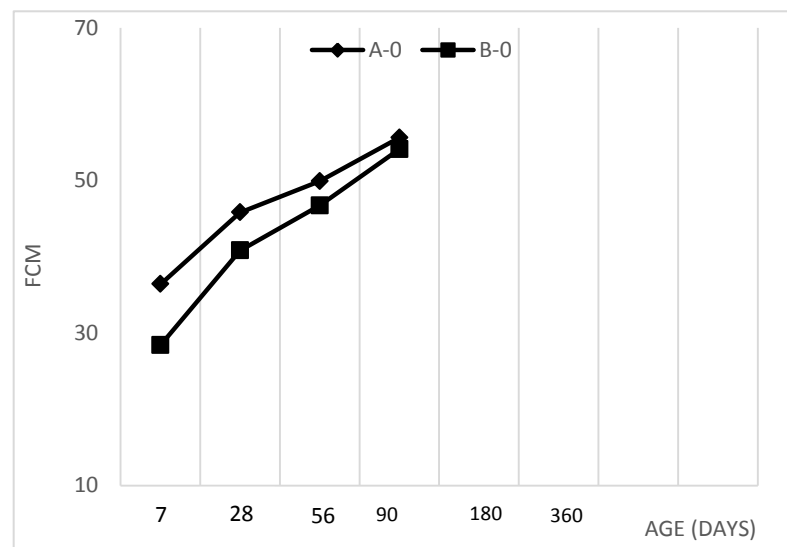


Fig.3: compressive strength of concrete versus hardening age

It should be noted also that the expansive component slightly reduces the compressive strength of concrete, especially at the early hardening period (fig.3). However, at the age of 90 day concrete strength of formulations A-0 and B-0 are almost equalized. The greatest decrease in concrete strength is observed at 7 days, probably, this period is connected with the formation of hydration products as calcium and magnesium hydroxides.

4. Conclusion

1. It was shown that the mix containing the higher dosage of admixture SRA gave higher slump flow diameter and the lower is the viscosity from other mixes.
2. It is shown that the admixture SRA reduces the compressive strength of concrete depending on dosage at early age, and at the project age of hardening. Taking into

account the plasticizing action of SRA it is possible to decrease the water-cement ratio without worsening the technological properties of the mixtures, which provides the removal of the negative influence of the admixture on the strength of the concrete.

3. It was shown that the combined application of an expanding component on the basis of CaO and MgO, and also a shrinkage-reducing admixture (SRA), leads to the better effect of the reduction of the value of the restrained shrinkage and the probability of a risk of crack-formation.

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